Determination of the Half-life of ^{37}Ar by Mass Spectrometry

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^{37}Ar is produced in nature by cosmic-ray spallation and by neutron capture processes, and decays by electron capture to ^{37}Cl. The half-life of this isotope is approximately 35 days. Knowledge of the half-life is important to ^{40}Ar/^{39}Ar dating[1] and various problems in cosmochemistry including neutrino detection[2]. Previous determinations[3-8] of the ^{37}Ar half-life have been based on activity measurements. Here we report mass spectrometric data monitoring the ratio of ^{37}Ar to stable ^{36}Ar as a function of time after neutron activation[9]. These data provide an independent corroboration of the activity-based results, and yield a more precise value for the half-life than all but the most recent of those experiments.

Optical grade fluorite (CaF_2) was irradiated in 11 distinct neutron irradiation runs of 7 to 100 hours duration at the 1 MW TRIGA reactor at Oregon State University. ^{37}Ar and ^{36}Ar are produced by fast neutrons via the ^{40}Ca(n,α)^{37}Ar and ^{40}Ca(n,nα)^{36}Ar reactions, respectively. Normalizing radioactive ^{37}Ar to stable ^{36}Ar enables using decay of the ^{37}Ar/^{36}Ar ratio to constrain the ^{37}Ar half-life. Because atmospheric ^{36}Ar is present in variable concentrations, a correction using ^{40}Ar is required. This correction, which assumes that all ^{40}Ar is of atmospheric origin, yields the reactor-produced ^{36}Ar ($^{36}Ar_{Ca}$). Analysis of unirradiated samples of the same fluorite confirms an atmospheric ^{40}Ar/^{36}Ar ratio. $^{36}Ar_{Ca}$ comprises 79-99% of all ^{36}Ar in the irradiated fluorite samples analyzed, and the atmospheric correction introduces small errors compared with those from mass spectrometry. For each analysis, 0.2 to 3 mg of irradiated fluorite were degassed in ultrahigh vacuum with either an argon-ion or a Nd-YAG laser, and purified gas was analyzed with a noble gas mass spectrometer. The amount of fluorite analyzed was adjusted to maintain ^{37}Ar yields at least 50 times background. The precision of individual ^{37}Ar/^{36}Ar measurements ranges from ±2% to ±35%, with a median of ±11%.

Argon ion beam currents were measured on a single electron multiplier using magnetic field switching to cycle sequentially between argon isotopes. All data reported herein are corrected for background (measured between every 1-3 samples) and mass discrimination (1.00282 ±0.00215 to 1.01133 ± 0.00200 per amu) based on average values of ^{40}Ar/^{36}Ar from air pipettes interspersed with unknowns.

Regression analysis of these data yields a value of 34.95 ± 0.08 days, which is at least twice as precise as all but the most recent of the previous activity-based measurements. The utility of methods involving mass spectrometry for determining decay constants has been exploited for several decades by earth scientists. To our knowledge, such experiments have always used ingrowth of a daughter nuclide rather than dimunition of the parent. In difficult cases, including that of ^{37}Ar which involves experimentally challenging detection of soft x-rays and/or Auger electrons, it would seem desirable for nuclear data evaluations such as ENSDF or NUBASE to expand their literature searches and take account of all relevant data.

Footnotes and References

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